2017

SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF A SOUTHEASTERN KENTUCKY DEER POPULATION

Caleb Anderson Haymes
University of Kentucky, haymes8@vt.edu
Digital Object Identifier: https://doi.org/10.13023/ETD.2017.495

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Caleb Anderson Haymes, Student

Dr. John J. Cox, Major Professor

Dr. Steven Price, Director of Graduate Studies

SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF A SOUTHEASTERN KENTUCKY DEER POPULATION

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Forest and Natural Resource Sciences in the College of Agriculture, Food and Environment at the University of Kentucky

By

Caleb Anderson Haymes

Chatham, Virginia

Director: Dr. John J. Cox. Professor of Forestry

Lexington, Kentucky

2017

ABSTRACT OF THESIS

SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF A SOUTHEASTERN KENTUCKY DEER POPULATION

White-tailed deer are one of the most sought after game species in Kentucky. While much of the Commonwealth boasts high deer populations, those in southeast Kentucky are viewed as relatively low compared to other regions, even after a decade of restrictive doe harvest and multiple years of population supplementation via translocation. We studied survival and cause specific mortality of a local population of deer near the Redbird District of the Daniel Boone National Forest in Clay and Leslie County, Kentucky from January 2014 - January 2017. We estimated female annual survival at 0.89 (CI: 0.88-0.87), with an overall 3-year survival of 0.69 (CI: 0.56-0.84). Deer vehicle collisions and poaching were the most frequent mortality causes and represented 13 of 18 (72%) of mortalities. Managers should consider all forms of mortality and their relative importance in wildlife population dynamics when making harvest decisions. We recommend longer-term studies similar to ours to better understand population trends and inform regional management of this species in Kentucky.

KEYWORDS: Appalachia, Kentucky, *Odocoileus virginianus*, Management, Population,

Survival, White-tailed Deer

___Caleb A Haymes________

_____12-13-2017____________

SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF A SOUTHEASTERN KENTUCKY DEER POPULATION

BY:

Caleb Anderson Haymes

______Dr. John J. Cox___________

Director of Thesis

______Dr. Steven Price__________

Director of Graduate Studies

______12-13-2017______________

Date

ACKNOWLEDGEMENTS:

Firstly, I would like to thank my Thesis Chair, Dr. John Cox. Without his support and guidance, this endeavor would have never come to fruition. Secondly, I would like to thank my fellow graduate student and friend Joe McDermott. Strength and resilience in the face of tough field work is how we persevered. Next, I thank the A-Team: Joe McDermott, Gabe Jenkins, John Hast, Will Bowling, Dan Crank, and Tina Brunjes. Thank you all for having faith in me and allowing me to undertake this project. Growing and learning beside you all before and throughout this project prepared me for success in whatever life throws my way. Also, thank you to all of the technicians who endured -20 degree nights and long hours to bring this project through.

Lastly, I would like to thank my wife. Katie, you are my rock. Thank you for being there for me and taking care of our lives while I was away. Without your patience and support none of this would have been possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Introduction

The status of many North American wildlife species was starkly different at the time of European settlement than today. Many species were common across the continent. American bison (*Bison bison*), eastern elk (*Cervus canadensis*), and white-tailed deer (*Odocoileus virginianus*) were abundant and widespread in the eastern U.S.; however, the lack of wildlife hunting laws and the need to feed a rapidly growing American human population led to overexploitation of several animal species. Species decline and range reduction was not limited to large mammals. The passenger pigeon (*Ectopistes migratorius*), probably the most abundant bird on Earth during colonial America, was extirpated, while other species like beaver (*Castor canadensis*), turkey (*Meleagris gallopavo*), and river otter (*Lontra canadensis*), also experienced range contraction and population declines (DeLime 1951) primarily caused by overexploitation.

At the turn of the 20th century, the establishment and implementation of wildlife and other natural resource regulations in North America led to the recovery of many game species (Demarais and Krausman 2000). Additional important components of the modern paradigm of wildlife conservation that have facilitated species recovery include animal reintroduction and supplementation of existing populations via the translocation of individuals; however, these ecologically restorative measures are fraught with challenges caused by perceived or real human-wildlife conflict (DeLime 1951, Gassett 2001).

Large mammal species such as mountain lions (*Puma concolor*), grey wolves (*Canis lupus*), and bear (*Ursus spp*.) have large space and other resource requirements that can prove difficult to satisfy in an increasingly human populated and developed world (Hebblewhite and Merrill 2008, Kertson et al. 2011, Mattson 1990). In addition, large mammals have low productivity (Gaillard et al. 2000) which further complicates long-term population viability, particularly where population sizes are small and managers are simultaneously tasked with maintaining harvestable numbers. These situations require careful monitoring of population parameters and consideration of inherent variation in models and analytical decisions used to generate them.

For large mammals and other wide-ranging species, a landscape-scale management approach is often recommended to account for geographical variation in population densities, human land use patterns, and availability of resources such as food, water, and cover (Wikramanayake et al. 1998). Many mammal populations are managed using blocks or units to tailor management to the immediate needs of the animal population (Christensen et al. 1993, Palsbøll et al. 2007). For instance, in an ecosystem where row-crop farming is the main land-use, white-tailed and other deer species require different management strategies than those in primarily forested ecosystems.

Brief History of Deer in Kentucky

Historically, white-tailed deer thrived in North America. Native Americans exploited populations of deer for food, clothing, and tools (McDonald et al. 2004). After the arrival of European settlers, it is likely that deer populations increased further after disease decreased Native American numbers (Adams and Hamilton 2011); however, deer population increases were short-lived. European exploitation of deer and changing land-use patterns caused dramatic decreases in deer populations (Halls 1978). But beginning in the late 19th century and continuing through the 20th century, wildlife/game management became a public priority. Laws such as the Lacey Act of 1900 were enacted to curtail interstate transport of illegally harvest wildlife (Adams and Hamilton 2011). Many wildlife agencies, particularly in the southern extent of deer range, implemented stocking, or reintroduction, programs to bring game animals back from historic lows (DeLime 1951).

In Kentucky, white-tailed deer inhabit many different ecosystems, ranging from the vast farmland of western Kentucky to the steep mountains in the east, and they are managed differently in those areas. Deer are currently managed in units based on county population; however, in the early 1900's deer were nearly extirpated (Barick 1951). In the 1920's, soon after the "exploitation era", deer numbers in Kentucky reached a historic low of ~2,700 animals (Barick 1951, Blackard 1971, Demarais and Krausman 2000). In 1946, the Kentucky Division of Game and Fish, the predecessor of the current Kentucky Department of Fish and Wildlife Resources, embarked on a deer restoration project to replenish deer populations in depleted ranges across the state (DeLime 1951). To augment deer numbers, a statewide trapping and translocation project was implemented (DeLime 1951). The Kentucky Woodlands National Wildlife Refuge, once located between the Cumberland and Tennessee Rivers in Trigg and Lyon counties, was the only area in the state that could sustain trapping efforts; thus, for the first few years of the project all deer trapping occurred there (Barick 1951). In 1946-47, Mammoth Cave National Park (MCNP), in Edmonson County, was one of the first places to receive white-tailed deer (Blackard 1971). Subsequently, the MCNP population grew quickly, and became the major source for further intrastate translocations, with approximately 61% of all relocated deer from 1946-69 sourced from the park (Blackard 1971).

Deer restoration continued throughout the state until the late 1960s. By June 1969, the Kentucky Division of Game and Fish had relocated just over 5,600 animals. At that time, the deer population was estimated to be ~ 65,000 animals (Blackard 1971). The population continued to increase through the 1970's and into the 1980's with a population estimated between 167,000 and 181,000 animals in 1983 (Phillips 1983). Although the total population of deer in the state continued to rise, the regional population in southeast Kentucky remained relatively low, spurring translocation efforts of ~500 deer to each of 28 counties in this area from 1984-98 to increase numbers. Soon after the restoration, deer herds in these counties appeared to have stabilized with populations numbering around 1000 animals per county (Gassett 2001). By the late 1990s, many of the southeastern counties' populations had risen to around 1500 animals per county; however, despite restrictive female harvest, many of these same counties for unknown reasons retain stagnated deer populations (Gabriel Jenkins, KDFWR unpubl. data 2013).

Deer Population Dynamics

The study of population dynamics can be defined as the study of the relationship between multiple aspects of wildlife populations, most notably productivity, growth, and survival (Willis et al. 2008). In birds, popular methods of analyzing local populations are point-count methods where observers count the number and species of birds within a certain sampling distance and time. With multiple data sets, managers can use this information to determine overall trends in regional and local populations (Hutto et al. 1986). In mammals, the mark-recapture method is commonly used to determine population trends, where individuals are marked, released, and captured again after a length of time. Once the animals are caught, various indices such as age and size are recorded and analyzed to monitor population health and influence management decisions. These and other methods are frequently used to examine population vital rates, including birth (reproduction), death, immigration, and emigration, which in turn can be used to model responses to key environmental determinants, such as food, competition, and predation (Willis et al. 2008). For large mammals, such as white-tailed deer, capturing, tagging, or marking (e.g. radio-telemetry), and subsequent monitoring (radio-telemetry and/or global positioning system) is currently accepted as the best method to analyze population dynamics with sufficient detail to inform most modern population models. Radio-telemetry has proven to be important for estimating key population parameters including survival and natality, and for characterizing spatial ecology and resource use patterns of many species.

Survival and Cause-specific Mortality

An estimate of survival can be defined as the chance that an individual has of surviving though a given time period. Survival of wild, free-ranging, animals is often difficult to estimate due to field-based challenges (e.g. low population density, difficulty in capturing or monitoring) inherent in obtaining sufficient sample sizes to satisfy statistical requirements (Murray and Patterson 2006). Yet even relatively small sample sizes can yield important information about causes of mortality that helps inform species management.

Adult white-tailed deer survival is highly variable depending on resource availability, disease, hunting pressure, and predation, and is a strong determinant of population growth and dynamics compared to juvenile survival or fecundity (Gaillard et al. 2000, Bender et al. 2007, DeYoung 2011). Environmental stochasticity, such as drought or disease, can significantly affect the rate of population growth (Bender et al. 2007). Adult white-tailed deer survival is typically high throughout its range; however, survival varies between sexes and age classes with adult males typically having lower survival rates than adult females (Nelson and Mech 1986, Fuller 1990, Nixon et al. 1991, Dusek et al. 1992, Van Deelen et al. 1997, Gaillard et al. 2000, Etter et al. 2002). Males typically have higher absolute energetic requirements and enter the winter in an energetically depressed state due to losses incurred during fall breeding (Nicholson et al. 1997). In addition, unequal hunting pressure further differentiates male and female survival with the former typically the preferred hunting demographic due to body size and antler presence (Dusek et al. 1989).

While obtaining survival estimates is useful for managers, understanding causes of mortality is essential to adaptively managing deer populations given the myriad of factors that can impact deer populations at multiple spatial and temporal scales. Mortality in deer populations can be caused by a myriad of factors that challenge species management. Common mortality factors of white-tailed deer include predation, harvest (legal and illegal), disease, and vehicle-collisions. Predation is often a leading factor of mortality where large apex carnivores are present. Cougar (*Puma concolor*) predation is a leading mortality factor in black-tailed deer (*Odocoileus hemionus columbianus*) populations in British Columbia (McNay and Voller 1995), and wolf (*Canis lupus*) predation is often the largest source of mortality in white-tailed deer in northern Minnesota (Nelson and Mech 1986, DelGiudice et al. 2002). With the recent range expansion of the coyote (*Canis latrans*), predation on deer neonates has become an important deer management issue in the Southeast U.S. (Kilgo et al. 2010).

Although the wolf and cougar are now absent from Kentucky, the black bear (*Ursus americanus*), coyote, bobcat (*Lynx rufus*), and domestic dog are all extant white-tailed deer predators. Black bear have recently recolonized southeast Kentucky from the neighboring states of West Virginia, Virginia, and Tennessee (Hast 2010). Black bear have been found to prey on white-tailed deer fawns and adults (Fuller 1990). Coyotes frequently prey upon adult and neonatal white-tailed deer (Messier et al. 1986, DePerno et al. 2000), and bobcats are found throughout much of Kentucky and are a well documented predator of deer (Marston 1942). Pais (1987) found domestic dogs to be a leading mortality factor in relocated deer in southeast Kentucky.

During the early decades of deer management in the U.S., populations were recovering from extensive over-harvest, and legal hunting had all but ceased in most areas as restocking and habitat manipulation efforts were widely implemented (Woolf and Roseberry 1998). Initial hunting regulations typically consisted of "buck-laws" allowing minimal female harvest to stimulate population growth, with regulations moving towards either-sex tag by the late 20th century (Woolf and Roseberry 1998). By the early 21st century, deer became overpopulated in many areas and hunting regulations became more liberal in allowing multiple does to be harvested in an attempt to regulate numbers (Van Deelen et al. 1997).

Proper management of harvested population requires an understanding of both hunting and non-hunting mortality, and how they are associated. Research has indicated that natural mortality is typically low for white-tailed deer and that hunting mortality has little to no effect on natural mortality (Dusek et al. 1992). In low populations, however, hunting mortality can lower non-hunting mortality through alterations of the age structure (Dusek et al. 1992). Hunting as a mortality factor can be split into two major groups: legal hunting and illegal hunting. In hunted populations, hunting mortality ranges from 5% (DeYoung 1989) to 72% (Van Deelen et al. 1997). In black-tailed deer, in Washington, McCorquodale (1999) found legal hunter harvest to be a leading mortality factor affecting bucks, and illegal hunting to be the primary cause of female deer mortality. Dusek et al. (1992) found that hunting, including legal harvest, wounding loss, and illegal harvest, was the greatest mortality factor affecting white-tailed deer in Montana. In Kentucky, illegal harvest has been documented in radio-collared deer (Pais 1987, Cox 2003). Illegal harvest can be motivated by many sources including money, food, social standing, trophy animals, disregard for the law, or for enjoyment (Muth and Bowe 1998). Wounding loss can be particularly problematic to factor into survival analyses and population models because it is largely unmonitored by most states. A few studies that have examined its impact on deer have indicated that wounding loss can be substantial. Pedersen et al. (2008) reports 18% wounding loss with modern archery equipment, and Ditchkoff et al. (1998) found that < 50% of archery shot deer are recovered.

The degree to which density affects the health of a population is vital information for managers to understand for sound management, and this relationship is often location-dependent given the wide variation of resource availability and other environmental factors that affect population dynamics. In white-tailed deer, all populations typically exhibit density dependent behavior (DeYoung 2011). High densities of deer can lead to overcrowding and increased likelihood for disease transmission as contact frequency among individuals increases (Williams et al. 2002).

There are numerous diseases that occur in white-tailed deer in the southeastern United States (Davidson 2006); however, few of these have significantly affected deer numbers in Kentucky. Chronic wasting disease (CWD) and Epizootic Hemorrhagic Disease (EHD) are two of the most important diseases that have major impacts on deer populations in the U.S. (Nettles and Stallknecht 1992, Campbell and VerCauteren 2011). CWD is a transmissible spongiform encephalopathy associated with the prion protein of the lymphatic system and the central nervous system first identified in the early 1980's, and once thought to be constrained to an area in Wyoming and Colorado (Williams 2005). Clinical signs of the disease include weight loss and abnormal behavior. Transmission among cervids is believed to be horizontal, or from animal to animal; therefore, bait stations could be an important vector for spread (Spraker et al. 1997). In Kentucky, the deer population has not been affected by CWD (Jenkins and Brunjes 2013); however, it has been found in 5 of 7 border states (USGS 2016). Epizootic Hemorrhagic Disease (EHD) has been found in southeastern deer populations since the late 1800s (Shope et al. 1960). Some of the clinical signs of EHD are depression, respiratory distress, swollen eyes and tongue, and deer will often be found near water

(Davidson 2006). In 1970, Hoff et al. (1973) reported approximately 10% of the local population succumbed to EHD in North Dakota. In 2007, EHD was reported throughout Kentucky and had a large impact on the population, killing thousands of deer (Jenkins and Brunjes 2013).

As deer numbers have dramatically increased, so have deer vehicle collisions (DVC) in the U.S. throughout the species range. State Farm, one of the nation's leading insurance agencies, estimated approximately 1.22 million deer collisions occurred in the United States, from July 2012-June 2013 (StateFarm 2013). The Kentucky State Police reported 3,108 deer-vehicle collisions in Kentucky in 2014 (KSP 2015). Romin and Bissonette (1996) surveyed 50 agencies on deer vehicle collisions, and report that in Kentucky, from 1982-1994 deer vehicle collisions increased 214%, a number likely to be a low estimate due to underreporting. In suburban Chicago, Etter et al. (2002) found vehicle collisions to be the largest cause of mortality in deer. In Florida Key deer (*Odocoileus virginianus clavium*), Lopez et al. (2003) found vehicle collisions caused nearly 50 percent of the total mortality, and that survival increased with distance from a major US highway. With populations of deer expanding and the number of vehicles increasing, deer-vehicle collisions will remain an important factor influencing deer population dynamics.

Fecundity

Fecundity is an important population parameter for mangers to understand. In white-tailed deer, fecundity can refer to the reproductive potential of a population. Ultrasonography and uterus dissections are two commonly used methods to derive this metric (Nixon 1971, Bingham et al. 1990). In good habitat, some fawns will breed and adult does will average >2 fawns per year (Haugen 1975). The rate of population growth can be better understood by examining the age-classes and the productivity of each age class. In Ohio, Nixon (1971) found a 76% ovulation rate in fawns. In contrast, only 1.8% of fawns were found to be pregnant, and 87.5% of yearlings were pregnant in Minnesota (DelGiudice et al. 2007); however, this difference could be attributed to the local habitat of the study sites. Juvenile (0.5 – 1.5 years old) productivity is often largely variable and can be more sensitive to population density, environmental cues, and food availability (Severinghaus and Cheatum 1956, Gaillard et al. 2000). Adult (>2.5 year old) deer productivity is relatively constant and less sensitive to such cues; nearly all (>90 percent) adult deer reproduce every year (Nixon 1971, Gaillard et al. 2000, DelGiudice et al. 2007). An understanding of reproductive ability is essential for managers to understand in concert with recruitment, or the number of fawns which survive to adulthood.

Knowing the percentage of individuals which produce young is just as important as knowing how many are produced. In white-tailed deer, natality can be defined as the number of fawns a doe gives birth to each year (Fortin et al. 2015), a measure that has been researched in several ways. In Ohio, Nixon (1971) dissected the reproductive tracts of hunter harvested deer to count the number of visible embryos or fetuses to estimate natality; however, it has been found that depending on the age and nutritional status of the doe, she may not successfully produce all of the young she carries in utero (Verme 1963). Visual surveys for fawns are also a commonly used method to assess production in deer, where researchers count the number of fawns seen per doe along predetermined transects (Lomas and Bender 2007). Opportunistic fawn catching has been used and is also known to have biases associated with vegetation type, proximity to roads, and the age of the fawns being captured (Ballard et al. 1998, Pojar and Bowden 2004). Both latter two methods give managers physical evidence of natality; however, uterus dissections leave out how many fawns are surviving to adulthood, and live fawn counts cannot capture the number of fawns which died before the count. Luckily for managers, there are now methods which can capture these indices and provide all the necessary data for white-tailed deer natality.

Vaginal implant transmitters (VIT) are becoming the norm for researchers to assess natality. A VIT is a radio transmitter which is implanted into the vagina of deer. Upon parturition, the transmitter will be expelled with the fawns, and a temperature switch will activate the transmitter to signal birth (Bishop et al. 2011). If located soon enough, the fawns will be hiding near the transmitter (birth-site) and can be found. They can then be collared and survival can be assessed using telemetry techniques. When used in conjunction with ultrasonography, researchers can assess the fetus retention rate, which can lead to a better understanding of which factors are limiting populations of deer (Smith and Lindzey 1982). Thus, the summation of all three techniques can give managers three necessary metrics to assess natality: fetus count, fawn production, and fawn survival.

White-tailed deer are an extremely adaptable species, having the largest range of any cervid in North America (DeYoung 2011), and as we've described, impact human livelihoods in a number of positive and negative economic and ecological ways. As with many habitat generalist species, wildlife managers often require site or region-specific knowledge about vital rates when making management decisions that affect deer numbers. Our research focused on a low density population of white-tailed deer in southeastern Kentucky that was thought to have had little to no population growth despite intensive restocking efforts. Specifically, We used radio-telemetry to estimate survival and determine cause-specific mortality of white-tailed deer at two study sites within this region.

Chapter 2: Survival and Cause-specific Mortality of a Southeast Kentucky Deer Population

Introduction

White-tailed deer (hereafter, deer) population growth and range recolonization during the past 125 years can be attributed to the success of reintroductions and management policies enacted during the 20th century (Hefflefinger 2010). Deer are the most frequently hunted big-game species in the United States, and contribute to local economies through hunting, tourism, and wildlife watching (Grado et al. 2007, Conover 2011). Although deer are considered overabundant and ecologically destructive in some areas of the U.S. (Waller and Alverson 1997, Stewart et al. 2007), many areas have deer populations below desired management.

Approximately 2000 deer remained in Kentucky in the early 20th century before extensive restocking and enforcement facilitated population growth (Gassett 2001) to a statewide estimate of approximately one million deer in 2012. Population growth was most rapid in the western two-thirds of the state, while that in southeastern Kentucky remained unsatisfactory despite hundreds of thousands of dollars spent on restocking efforts that lasted through 1998 (Gassett 2001). Previous research in southeast Kentucky observed harvest (both legal and illegal) and feral dogs as influential mortality sources for deer (Cox 2003, Pais 1987), while some stakeholders blamed the recently arrived coyote for stagnant deer numbers. We used radio-telemetry to assess survival and cause-specific mortality of white-tailed deer in southeastern Kentucky to investigate factors that could be responsible for suppressing regional population growth. Given past observations during formal deer studies, anecdotal information from local hunters and wildlife biologists, and the perception of low regional deer numbers, we hypothesized that poaching and road collision would be primary sources of mortality in this region and that annual survival estimates would be low (< 50%).

METHODS

Study Area

Our study was conducted in Clay County and Leslie County, KY, USA, located in the Cumberland Plateau physiographic region of Kentucky. Clay County encompasses 758 km^2 and Leslie County encompasses 650 km^2; relatively steep mountains typical of the Central Appalachian mountain range characterize both. Elevation ranges from 366-671 m, and ridges are frequently dissected by deep dendritic drainages (Moore and Dotson 2003) leading to small river and creek bottoms. Flatter slopes are present along the rivers and creek drainages; roads, farms, and agricultural fields or small grasslands often occur in these floodplains. Average annual rainfall in this region is 130 cm (51 in) and average temperatures range from -5.5 Cº (22º F) to 28.9º C (84º F) (USCD 2016).

Research was conducted in two focal areas with very similar land cover types in Clay County and Leslie County; Oneida and Redbird (Figure 2.1). The Oneida Study Area was comprised mostly of private land (67.9%) with smaller blocks of the Daniel Boone National Forest scattered around the township of Oneida, KY. The township is located at the confluence of the Redbird River and Goose Creek, which form the headwaters of the South Fork of the Kentucky River. The Redbird Study Area was 66.8% publicly owned and is operated by the U.S. Forest Service as part of the Daniel Boone

National Forest and Redbird Wildlife Management Area (WMA). All portions of both study areas are open to public hunting under statewide regulations. We determined general land cover types of the two focal areas by using the Raster Clip tool in ArcGIS version 10.2 (ESRI, Redlands, CA) to clip the 2011 National Land Cover Dataset (Homer et al. 2015) using a 203.3 km^2 (8 km radius) circle that encompassed the trap sites within each study area. The Oneida study area was comprised of 84.6% mixed-mesophytic forest, 9% pasture, 5.3% human settlement, 1% open water, and 0.1% crops. The Redbird study area was comprised of 87.4% mixed-mesophytic forest, 7.4% pasture, 4.7% human settlement, and 0.5% open water. Oak-hickory-beech (*Quercus-Carya-Fagus*) forests dominated the forests of the study area. Other co-dominant trees species including red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), and yellow poplar (*Liriodendron tulipifera*). Pastures were comprised of tall fescue (*Schedonorus arundinaceus*) and various clovers (*Trifolium* spp.). Soybeans (*Glycine max*) and corn (*Zea mays*) were the most common commercial crops.

Deer were captured using a 18.3 m (60 ft.) x 18.3 m (60 ft.) drop net, 17.4 m (47 ft.) x 13.1 m (43 ft.) rocket nets (17.4 mx by 13.1 m), and 1.83 m (6 ft.) long x 0.91 m (3 ft) wide x 1.22 m (4 ft.) tall Clover traps (Clover 1956) baited with shelled corn. Clover traps were deployed in forests and in grassy clearings where space was insufficient to deploy drop-nets, and were checked every 12 hours. The rocket net was propelled by four Winn Star Type 15 rockets (Winn Star Inc., Carbondale, Illinois, USA) fired from an elevated tri-pod stand measuring 1.2 m high. The rockets were wired in sequence to a Handi-Blaster firing mechanism (Blasters Tool and Supply Co., Inc., Lawrenceburg, Kentucky, USA) with 20-gauge lamp cord. Deer activity at drop and rocket net sites was monitored by observing deer from vehicles using a forward looking infrared scope (Scout II 320, FLIR Systems Inc.) and by using a single trail camera (Bushnell Trophy Cam 8MP) mounted to a pole.

We physically immobilized and blindfolded deer, then intramuscularly injected them in the shoulder or hip with 1-1.5 mL of BAM (Butorphanol Tartrate 27.3 mg/mL - Azaperone Tartrate 9.1 mg/mL- Medetomidine HCl 10.9 mg/mL) (Zoopharm INC., Laramie, Wyoming, USA) (Mich et al. 2008) per ZooPharm guidelines according to general age class (juvenile = <1 y.o.) or adult = >1 y.o.). We recorded heart rate and dissolved oxygen levels using a Masimo Radical 5 pulse oximeter (Masimo Corporation, Irvine, California, USA), and recorded breathing rate and temperature using visual cues and a rectal thermometer, respectively; these physiological parameters were collected at ~5-minute intervals. Juvenile and adult does were fitted with a Lotek LMRT-2 (Lotek Inc, Newmarket, Ontario, Canada) very high frequency (vhf) radio collar equipped with a mortality sensor that changed pulse rate when the collar remained motionless for > 4 hours. We fitted each deer with a uniquely numbered 2.5-cm plastic stud ear-tag (National Band and Tag, Newport, Kentucky, USA) inscribed with study personnel contact information to facilitate communication when a deer was harvested or found dead. We administered a submucosal dental nerve block of 2% Lidocaine solution (Hospira Inc., Lake Forest, IL) in the mandible gumline, and then pulled the fourth incisor for cementum annuli age analysis (Gilbert 1966). We also recorded standard body measurements including weight, total body length, chest girth, hind-leg length, and front shoulder length (Bender et al. 2007). Does estimated to be ≥ 2 years of age or older were fitted with a vaginal implant transmitter (Bishop et al. 2011; Advanced Telemetry

Systems, Isanti, MN, USA) to facilitate the capture of fawns for a companion study. We antagonized BAM using 2-3 mL (according to age) of Atipamezole (25 mg/mL) and 0.5-1 mL of Naltrexone HCl (50 mg/mL) (Zoopharm INC., Laramie, Wyoming, USA), then observed the study animal from ~ 25 m away until they successfully regained safe mobility. All capture and handling procedures were approved by the University of Kentucky IACUC #2013-1138.

We monitored radio-collared deer via triangulation and homing using ground telemetry or aerial telemetry from a fixed-wing aircraft. Deer were located daily using ground telemetry during the first four weeks post-capture to detect potential capture myopathy deaths, and weekly thereafter. We classified mortalities as roadkill if deer were discovered ≤ 20 m of a roadway, if we found broken vehicle parts near deer carcasses, and/or when impact trauma (e.g., road rash, bruising, and hair on the roadway) was evident. We classified a deer as illegally harvested when radio-collars were found cut off of the deer, and/or collars were found with no evidence of predation and no typical hunter-killed gut piles near the collars, and when deer were harvested outside of legal harvest seasons. The presence of all-terrain vehicle tracks and/or a hidden collar (one that appeared to be a deliberate human act of concealment), were also considered supporting evidence of illegal harvest. A deer was classified as harvested/hunted when it was reported or communicated with us directly. Death from illness was determined from lab results after submission to the Southeastern Cooperative Wildlife Disease Study. A predation event was determined by the presence of subcutaneous bruising typical of bite pressure from a predatory attack. Illness and predation were pooled for analysis due to the low sample size of each mortality cause and together were considered “natural causes.”

We determined survival estimates using the Kaplan-Meier estimator modified for staggered entry (Pollock et al. 1989). A Mantel-Haenszel log-rank test was performed to determine statistical differences between years, ages (juvenile vs adult), and study areas (Mantel and Haenszel 1959). We also estimated cause-specific mortality rates using Cox proportional-hazards regression modelling (Cox 1972). RStudio Version 1.0.136 with the Survival Package was used to calculate survival and mortality (Therneau 2015). Deer were right censored from the survival analysis if they were believed to have succumbed to capture myopathy, radio contact was lost, or the collar slipped off. We considered deer that died within four weeks of capture to have succumbed to capture myopathy, and these individuals were removed from the survival analysis (Haulton et al. 2001). Does which were < one-year-old at the time of capture were included in the study because they are part of the huntable population, and thus subject to the same mortality pressures as adults.

Results

From 2014-16 we captured 97 (2014 = 5 JF, 21 AF; 2015 = 14 JF, 22 AF; 2016 = 13 JF, 22 AF) individual does; 95 were collared and monitored for 50,471 radio-days with an average of 531 radio-days per doe. One adult and one juvenile doe died during the capture process and were never fitted with a collar (2.1%), and two (2.1%) adult does died from capture myopathy within 12 days post-capture, resulting in 93 does included in the survival analysis. Five (5.3%) juvenile does slipped their collars or lost collar signal and were subsequently right censored at those time periods. Because we found no significant differences in estimate annual survival between years (p = 0.55), age classes (p = 0.80) or study areas (p=0.97), we report annual survival estimates and mortalities pooled from adults and juveniles. Estimated annual doe survival was 0.89 (95% CI=0.55-0.94) in 2014, 0.86 (95% CI=0.78-0.96) in 2015, and 0.91 (95% CI=0.85-0.98) in 2016. The estimated survival of female white-tailed deer in our study area during the 3-year study period was 0.69 (95% CI=0.56-0.84) (Figure 2.2).

Eighteen (18.6%) does died during the study. Vehicle collisions caused 8 of 18 (44.4%) deaths (2014 = 2, 2015 = 4, 2016 = 2) for a mortality rate of 0.22 (SE:0.08). Illegal harvest accounted for five deaths (27.7%, 2015 = 1, 2016 = 4; mortality rate = 0.07, SE: 0.03), while legal harvest accounted for three of 18 (16.7%, 2015 = 2, 2016 = 1) deaths for a mortality rate of 0.05 (SE:0.03). Two does (11.1 %, 2016 = 2) died from natural causes (illness = 1 and predation = 1) with a mortality rate of 0.03 (SE:0.02). One doe died from apparent complications of cancer whereby intestinal epithelial lesions appear to have allowed bacteria into the bloodstream causing sepsis; tumors were also found in the liver and lungs (Southeastern Cooperative Wildlife Disease Study, College of Veterinary Medicine, University of Georgia, Athens, Georgia, USA).

Discussion

Climate change (Unsworth et al. 1999, Samuel 2007), disease transmission (McNay and Voller 1995, Bleich et al. 2015), and predation (Keller et al. 2015) have been implicated as causes of population decline in several species of North American ungulates. Although predation (Patterson et al. 2002), disease (Nettles and Stallknecht 1992), and deer vehicle collisions (Etter et al. 2002) can be major contributors of deer mortality in some areas, hunting is by far the largest source of deer mortality in most areas of the U.S. (Nelson and Mech 1986, Dusek et al. 1992, Van Deelen et al. 1997).

Surprisingly, given the low deer numbers that have plagued this region for decades, we found doe survival in southeastern Kentucky to be much higher than predicted, even exceeding comparable studies (Table 2.1; Figure 1; Dusek et al. 1992, McCorquodale 1999, DePerno et al. 2000, Etter et al. 2002, Patterson et al. 2002, Robinson et al. 2002). Only three study animals were legally harvested (all with archery) during the 3-year study period, and the resultant hunter harvest mortality rate (0.05 SE: 0.03) was similar to other studies where doe harvest is allowed (Table 2.1; Van Deelen et al. 1997, DePerno et al. 2000, Patterson et al. 2002, Campbell et al. 2005). High survival rates of white-tailed deer females in a hunted population may be a function of restrictive doe-hunting regulations (Van Deelen et al. 1997), as applicable to our study area. Jacques et al. (2011) found that radio-collars may influence a hunter’s decision to legally harvest an animal. We undertook public education measures to inform hunters in the study area that radio-collared deer were legal quarry, but we were unable to identify any potential bias against harvesting our study animals that may have affected survival rates.

Poaching can undermine deer management goals. McCorquodale (1999) found illegal harvest to be the leading cause of female mortality of black-tailed deer in Washington. We found illegal harvest (0.07, SE: 0.03) in our study to be slightly higher than other reported estimates (0.02 – 0.06; Table 2.1; Nelson and Mech 1986, Nixon et al. 1991, Etter et al. 2002, Patterson et al. 2002, Fuller 1990, Storm et al. 2007). Illegal harvest was identified as the cause of death of five radio-collared deer in our study; three of the cases involved does killed during a buck-only hunting season, and two others were killed outside of any deer hunting season. Muth and Bowe (1998) suggested most poaching events occur during the hunting season under the guise of legal harvest. Studies of poaching in the U.S. reported low (1:83 – 1:30) ratios of reported incidences to actual incidences, suggesting that the amount of poaching that mangers know of through law enforcement is only a small portion of the actual amount of poaching (Vilkitis 1968, Kaminsky 1974, Green et al. 1988, Eliason 2003).

We found vehicle collisions were a major cause of deer mortality in our relatively low road density rural study area, and were higher (0.22, SE: 0.08) than other studies (Table 2.1; Etter et al. 2002, Robinson et al. 2002). It should be noted, however, that due to capture method constraints and trapping success, deer in our study were primarily captured in or near river bottoms where roads co-occurred (Finder et al. 1999), which could have inflated the relative importance of vehicle collisions as a source of regional deer mortality. Convenience sampling plagues many wildlife studies and thus caution should be exercised when statistics are extrapolated to the broader population (Nusser et al. 2008). Nonetheless, Ng et al. (2008) reported a positive association between deer-vehicle collisions, riparian areas, and non-forested agricultural areas. Grilo et al. (2011) found that curved roads, as frequently occurred in our study area, can lead to increased deer-vehicle collisions.

White-tailed deer are susceptible to a myriad of diseases (Davidson 2006), but only one deer in our study died from disease complications (cancer). In Kentucky, the most influential disease affecting white-tailed deer populations is epizootic hemorrhagic disease (EHD) (Nettles and Stallknecht 1992). EHD has been well documented in our study area, but we did not observe any mortality associated in EHD infected deer during the study time-period (Jenkins and Brunjes 2013); however, a major regional outbreak of EHD subsequently occurred during summer and fall 2017 throughout much of eastern Kentucky.

In areas where large carnivores are present, predation can strongly influence deer population dynamics (Nelson and Mech 1986, Fuller 1990, DelGiudice et al. 2002). Predation on adult deer in the Southeast U.S. was likely drastically different 250 years ago when wolves and cougars were extant. In the absence of these large predators, coyote, black bear, bobcat, and feral dog have become the primary predators of deer. In North Carolina, Chitwood et al. (2015) reported four confirmed predation events on healthy, adult female white-tailed deer by coyotes. Other studies suggest that the recent invasion of the western coyote into the east may significantly impact deer populations in the southeastern U.S. (Kilgo et al. 2010). We observed one adult doe that had been predated (species undetermined), although it should be noted that this individual experienced a difficult capture with a prolonged induction period whereby it survived past the one-month capture myopathy window, but remained within 200 m of the trapping location until a mortality signal was detected. It is possible that a weakened condition brought about by capture stress facilitated predation.

Management Implications

Ideally, single-species management would rely on use of the best available data to inform decision-making. Managers may need more specific data (e.g. local cause-specific mortality) to inform management at regional or smaller scales, particularly in areas where traditional management through the adjustment of hunting seasons, does not result in typical population reactions. Although this study was conducted over a relatively short period (3 years), it provided a window of insight into factors influencing population dynamics in a region of relative low deer density. Despite the recent establishment of a mesopredator, the coyote, in our study area, we found vehicle collisions and harvest (legal and illegal) to be the two primary causes of adult deer mortality in southeastern Kentucky. Given the relatively high annual estimated survival (0.89), our findings suggested that factors other than adult survival, such as fawn survival or habitat quality and availability, may play a relatively more important role in regional deer population dynamics. Managers in Kentucky, and in other similar habitats, however, can now utilize the most recent and relevant survival data from our study to inform population models in the region. We highly recommend that long-term monitoring of population metrics (survival, natality) be accompanied by resource selection studies to better understand factors responsible for the relatively low deer densities that have long plagued wildlife managers and frustrated hunters in this region.

Table 2.1

Select survival and cause-specific mortality rates of white-tailed deer across the eastern U.S.

Study	Survival Rate	Mortality (SE) Hunting	Poaching	Roadkill	Natural[a]
This study	**0.89**	**0.05**	**0.07**	**0.22**	**0.02**
Campbell et al. 2005	0.88	0.04			0.08
Cox 2003	0.87				
Storm et al. 2007	0.87	0.09	0.02	0.02	
Etter et al. 2002	0.83	0.02	0.03	0.08	
Patterson et al. 2002	0.80	0.02	0.06		0.07
Chitwood et al. 2015	0.80				
VanDeelen et al. 1997	0.77	0.04			0.08
Brinkman et al. 2004	0.75				
Kunkel and Pletscher 1999	0.74				0.23
Fuller 1990	0.69	0.15	0.05		0.06
DePerno et al. 2000	0.57	0.04			0.12

[a] Includes predation and illness

Figure 2.1

Map of Oneida and Redbird white-tailed deer study areas in Clay and Leslie County, KY, 2014-17.

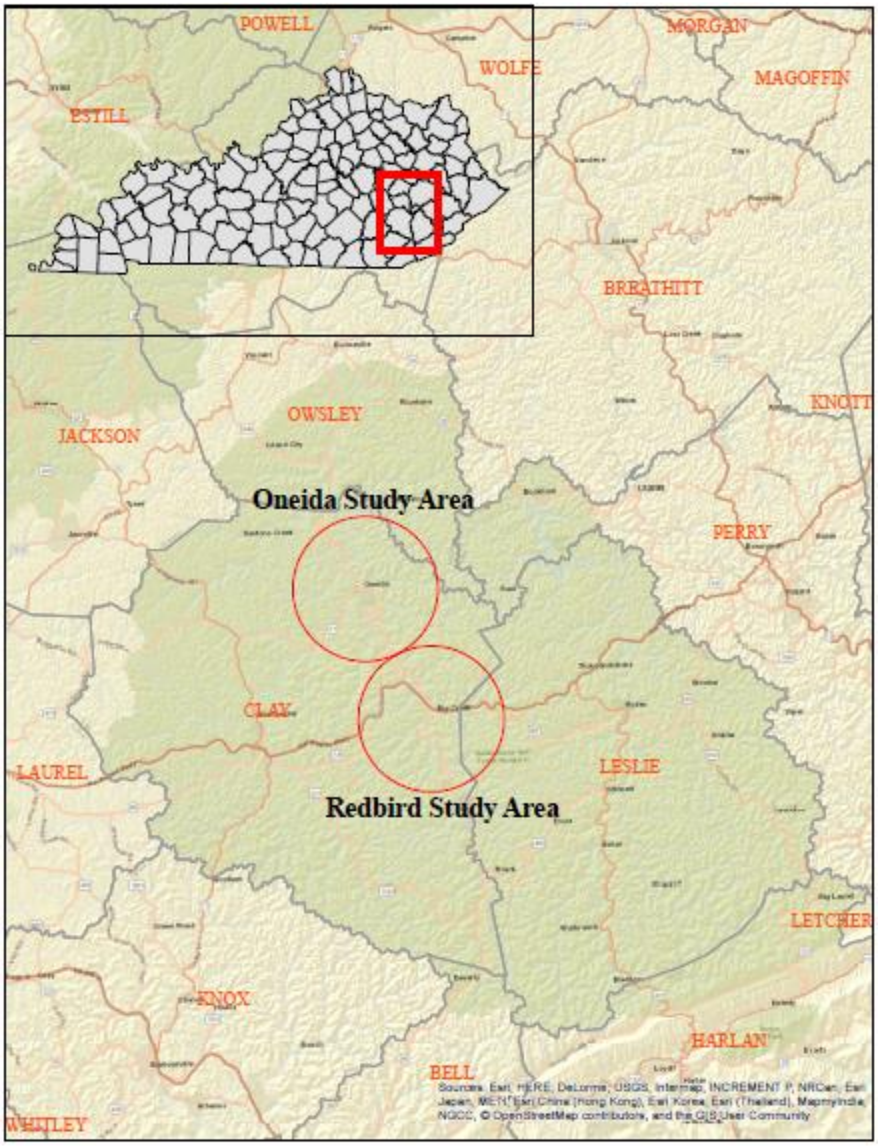

Figure 2.2

Kaplan-Meier survival curve for adult white-tailed deer in Southeast KY, 2014-17. Confidence intervals are presented as dotted lines with the survival estimate as a solid line.

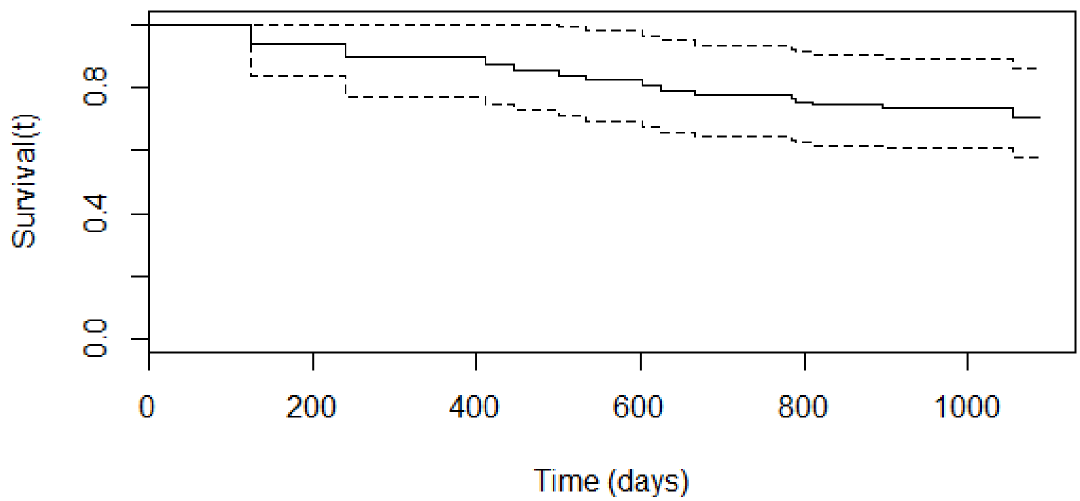

Figure 2.3 Appendix 1

Radio-collared white-tailed deer does monitored in Clay County, KY, 2014-17.

Ear Tag	Capture Date	Event Date	Days Monitored	Event Type	Age	Total Length (cm)	Shoulder Height (cm)	Weight (kg)
12	1/23/2014	9/19/2014	239	Roadkill	0.5	147.3	90.2	41.7
109	1/23/2014	1/15/2017	1088		2.5	173.0	91.4	55.3
57	1/24/2014	1/15/2017	1087		6.5	178.4	96.8	64.4
10	1/28/2014	1/15/2017	1083		14.5	170.5	84.5	59.9
1	2/4/2014	2/8/2014	4	Myopathy				
20	2/11/2014	3/3/2016	751	Illness	10.5	167.6	94.6	61.2
25	2/11/2014	1/15/2017	1069		1.5	162.6	88.9	
72	2/15/2014	5/27/2014	101	Roadkill	2.5	166.4	95.3	59.9
24	2/23/2014	1/15/2017	1057		1.5	175.3	94.0	55.3
8	2/24/2014	NA	0	Myopathy				
40	2/24/2014	1/15/2017	1056		9.5	166.4	96.5	60.8
17	3/15/2014	1/15/2017	1037		2.5	168.9	99.4	
21	3/20/2014	8/1/2014	134	Censor [b]	1.5	172.7	97.8	64.4
38	3/21/2014	1/15/2017	1031		7.5	178.4	101.9	55.3
39	3/21/2014	4/13/2015	388	Roadkill	3.5	173.0	97.8	48.5
7	3/22/2014	1/15/2017	1030		0.5	139.7	81.9	
30	3/22/2014	1/15/2017	1030		3.5	158.1	91.4	50.8
64	3/22/2014	10/10/2015	567	Hunting	3.5	157.5	96.5	57.6
31	4/1/2014	12/12/2016	986	Poach	3.5	167.6	98.7	63.5
52	7/21/2014	1/15/2017	909		3.5			
66	7/21/2014	1/15/2017	909		0.5	153.0	83.8	43.1
50	7/21/2014	8/2/2014	12	Myopathy	2.5	152.4	83.8	43.1
61	7/22/2014	1/15/2017	908		10.5	170.5	93.7	
69	7/22/2014	1/15/2017	908		0.5	149.9	88.9	57.6
58	7/28/2014	1/15/2017	902		8.5	177.8	101.6	63.5
56	7/30/2014	1/15/2017	900		0.5	158.8	85.7	43.1
33	1/14/2015	1/15/2017	732		0.5	151.1	81.3	38.6
11	1/22/2015	1/15/2017	724		0.5	142.9	80.3	44.0
13	1/22/2015	1/15/2017	724		0.5	144.1	82.6	43.1
29	1/22/2015	1/15/2017	724		2.5	164.1	93.3	64.4
15	2/3/2015	3/8/2015	33	Roadkill	0.5	135.9	74.9	39.5
26	2/3/2015	1/15/2017	712		0.5	159.4	82.9	34.9
27	2/3/2015	1/15/2017	712		0.5	158.8	84.1	46.7
42	2/3/2015	11/21/2015	291	Roadkill	13.5	175.3	96.5	67.1
44	2/9/2015	7/8/2015	149	Roadkill	7.5	168.9	93.3	70.3
23	2/13/2015	1/15/2017	702		2.5	158.8	89.5	59.0

Figure 2.3
(continued)

49	2/22/2015	1/15/2017	693		6.5	159.7	92.4	
19	2/23/2015	1/15/2017	692		5.5	177.8	92.1	61.2
36	2/23/2015	1/15/2017	692		6.5	160.0	91.8	54.4
18	2/24/2015	1/15/2017	691		0.5	155.3	82.6	36.3
37	2/24/2015	1/15/2017	691		9.5	168.3	83.2	52.2
67	2/27/2015	7/5/2016	494	Roadkill	0.5	137.8	80.6	35.4
68	2/27/2015	1/15/2017	688		5.5	165.7	96.2	61.7
59	3/1/2015	1/15/2017	686		1.5	136.8	88.3	58.1
41	3/2/2015	1/15/2017	685		1.5	162.2	87.9	46.7
35	3/3/2015	1/15/2017	684		0.5		84.1	
51	3/6/2015	1/15/2017	681		0.5	138.4	81.9	38.6
2	3/7/2015	1/15/2017	680		0.5	143.8	80.0	35.4
3	3/14/2015	1/15/2017	673		13.5	180.7	95.9	73.9
71	3/15/2015	6/6/2015	83	Poach	11.5	162.2	94.6	60.3
4	3/27/2015	1/15/2017	660		6.5	174.0	97.2	64.9
32	3/27/2015	1/15/2017	660		0.5	144.8	81.6	35.4
46	3/27/2015	1/15/2017	660		1.5	156.5	91.4	55.3
183	4/5/2015	1/15/2017	651		3.5	162.6	93.7	
34	4/14/2015	1/15/2017	642		0.5	159.1	85.7	
74	4/14/2015	9/17/2015	156	Hunting	4.5	169.5	91.8	
75	4/14/2015	1/15/2017	642		0.5			
167	4/15/2015	1/15/2017	641		1.5	159.4	87.6	56.7
189	7/10/2015	1/15/2017	555		4.5	168.3	92.1	66.2
179	7/15/2015	12/12/2016	516	Hunting	2.5	154.0	90.2	53.5
188	7/18/2015	1/15/2017	547		2.5	160.7	91.4	
138	7/23/2015	1/15/2017	542		13.5	176.2	92.7	58.1
73	1/6/2016	12/21/2016	350	Poach	7.5	166.4	91.1	65.8
146	1/8/2016	1/15/2017	373		1.5	145.1	84.5	47.6
184	1/9/2016	1/15/2017	372		2.5			63.5
182	1/11/2016	1/15/2017	370		2.5	152.1	95.9	
232	1/11/2016	3/22/2016	71	Poach	0.5	133.0	73.3	
178	1/11/2016	1/15/2017	370		0.5	127.0	72.4	24.9
227	1/12/2016	1/15/2017	369		0.5	145.4	86.4	
214	1/12/2016	1/15/2017	369		6.5	163.8	93.0	
228	1/12/2016	3/16/2016	64	Roadkill	1.5	152.4	94.6	52.2
185	1/14/2016	4/9/2016	86	Censor [a]	0.5	133.0	77.5	
147	1/16/2016	1/15/2017	365		2.5	168.0	95.9	
221	1/16/2016	1/15/2017	365		0.5	133.7	46.7	22.7
223	1/18/2016	1/15/2017	363		6.5	168.3	96.2	52.2
166	1/23/2016	1/15/2017	358		0.5	136.5	72.7	25.4
171	1/24/2016	1/15/2017	357		5.5			

Figure 2.3
(continued)

231	1/24/2016	1/15/2017	357		2.5			
217	1/25/2016	1/15/2017	356		0.5	135.3	74.9	24.9
180	1/25/2016	1/15/2017	356		2.5	184.2	96.2	59.0
80	1/28/2016	12/12/2016	319	Poach	0.5	148.6	83.5	29.5
222	1/29/2016	1/15/2017	352		5.5	167.0	84.1	63.5
225	2/4/2016	1/15/2017	346		3.5			54.4
190	2/5/2016	1/15/2017	345		4.5	174.6	83.2	54.4
154	2/10/2016	1/15/2017	340		0.5	146.1	81.3	
229	2/10/2016	1/15/2017	340		7.5			
174	2/10/2016	1/15/2017	340			170.8	94.0	
233	2/11/2016	4/9/2016	58	Censor [a]	0.5	137.2	76.2	36.3
191	2/12/2016	1/15/2017	338		1.5			
193	2/12/2016	1/15/2017	338		14.5			
207	2/14/2016	1/15/2017	336		7.5	170.2	92.1	61.2
213	2/16/2016	4/11/2016	55	Predation	0.5			
208	2/18/2016	4/4/2016	46	Censor [a]	0.5	132.1	82.6	36.3
187	2/21/2016	1/15/2017	329	Censor [a]	15.5	163.5	84.8	
250	3/16/2016	1/15/2017	305		0.5	141.0	76.8	
212	3/25/2016	1/15/2017	296			140.7	84.1	
249	3/30/2016	1/15/2017	291			174.3	87.6	54.4

[a] collar slipped off [b] lost collar signal

Literature Cited

Adams, K. P., and J. R. Hamilton. 2011. Management history. Pages 355-378 in D. G. Hewitt, editor. Biology and Management of White-tailed Deer. CRC Press, Boca Raton, Florida, USA.

Ballard, W., H. Whitlaw, D. Sabine, R. Jenkins, S. Young, and G. Forbes. 1998. White-tailed deer (*Odocoileus virginianus)* capture techniques in yarding and non-yarding populations in New Brunswick. Canadian Field-Naturalist 112:254-261.

Barick, F. B. 1951. Deer Restoration in the southeastern United States. Procedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners. 5:1-18.

Bender, L. C., L. A. Lomas, and J. Browning. 2007. Condition, survival, and cause-specific mortality of adult female mule deer in north-central New Mexico. Journal of Wildlife Management 71:1118-1124.

Bingham, C., P. Wilson, and A. Davies. 1990. Real-time ultrasonography for pregnancy diagnosis and estimation of fetal age in farmed red deer. Veterinary Record 126:102-106.

Bishop, C. J., C. R. Anderson, D. P. Walsh, E. J. Bergman, P. Kuechle, and J. Roth. 2011. Effectiveness of a redesigned vaginal implant transmitter in mule deer. The Journal of Wildlife Management 75:1797-1806.

Blackard, J.J. 1971. Restoration of the white-tailed deer in the southeastern United States. Thesis, Louisiana State University, Baton Rouge, Louisiana, USA.

Bleich, V. C., C. K. Johnson, S. G. Torres, J. H. Davis, J. M. Ramsey, J. T. Villepique, and B. J. Gonzales. 2015. Psoroptes infestation and treatment in an isolated population of bighorn sheep (*Ovis canadensis*). Journal of Zoo and Wildlife Medicine 46:491-497.

Brinkman, T. J., J. A. Jenks, C. S. DePerno, B. S. Haroldson, and R. G. Osborn. 2004. Survival of white-tailed deer in an intensively farmed region of Minnesota. Wildlife Society Bulletin 32:726-731.

Campbell, T. A., B. R. Laseter, W. M. Ford, and K. V. Miller. 2005. Population characteristics of a central Appalachian white-tailed deer herd. Wildlife Society Bulletin 33:212-221.

Campbell, T. A., and K. C. VerCauteren. 2011. Diseases and parasites. Pages 219-249 *in* D. G. Hewitt, editor. Biology and Management of White-tialed Deer. CRC Press, Boca Raton, Florida, USA.

Chitwood, M. C., M. A. Lashley, J. C. Kilgo, C. E. Moorman, and C. S. Deperno. 2015. White-tailed deer population dynamics and adult female survival in the presence of a novel predator. The Journal of Wildlife Management 79:211-219.

Christensen, A. G., L. J. Lyon, and J. W. Unsworth. 1993. Elk management in the Northern Region: considerations in forest plan updates or revisions. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. General Technical Report INT-303. Ogden, Utah, USA.

Clover, M. R. 1956. Single-gate deer trap. California Fish and Game 42:199-201.

Conover, M. R. 2011. Impacts of deer on society. Pages 399-409 *in* D. G. Hewitt, editor. Biology and Management of White-tailed Deer. CRC Press, Boca Raton, Florida, USA.

Cox, D. R. 1972. Regression models and life-tables. Journal of the Royal Statistical Society. Series B (Methodological):187-220.

Cox, J. J. 2003. Community dynamics among reintroduced elk, white-tailed deer, and coyote in southeastern Kentucky. Dissertation, University of Kentucky, Lexington, Kentucky, USA.

Davidson, W. R. 2006. Field manual of wildlife diseases in the southeastern United States. 3rd edition. Southeastern Cooperative Wildlife Disease Study, College of Veterinary Medicine, University of Georgia, Athens, Georgia, USA.

DelGiudice, G. D., M. R. Riggs, P. Joly, and W. Pan. 2002. Winter severity, survival, and cause-specific mortality of female white-tailed deer in north-central Minnesota. The Journal of Wildlife Management 66:698-717.

DelGiudice, G. D., M. S. Lenarz, and M. C. Powell. 2007. Age-specific fertility and fecundity in northern free-ranging white-tailed deer: evidence for reproductive senescence? Journal of Mammalogy 88:427-435.

DeLime, J. 1951. Live trapping and restocking. Kentucky Division of Game and Fish. Frankfort, Kentucky, USA.

Demarais, S., and P. R. Krausman. 2000. Ecology and management of large mammals in North America. Prentice Hall. Upper Saddle River, New Jersey, USA.

DePerno, C. S., J. A. Jenks, S. L. Griffin, and L. A. Rice. 2000. Female survival rates in a declining white-tailed deer population. Wildlife Society Bulletin 28:1030-1037.

DeYoung, C. A. 1989. Mortality of adult male white-tailed deer in south Texas. The Journal of Wildlife Management 53:513-518.

DeYoung, C. A. 2011. Population dynamics. Pages 147-181 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Ditchkoff, S.S., E.R. Welch Jr, R.L. Lochmiller, R.E. Masters, W.R. Starry, and W.C. Dinkines. 1998. Wounding rates of white-tailed deer with traditional archery equipment. Procedings of the Annual Conference of Southeast Assocation of Fish and Wildlife Agencies 52:244-248.

Dusek, G. L., R. J. MacKie, J. D. Herriges, and B. B. Compton. 1989. Population ecology of white-tailed deer along the lower Yellowstone River. Wildlife Monographs 104:3-68.

Dusek, G. L., A. K. Wood, and S. T. Stewart. 1992. Spatial and temporal patterns of mortality among female white-tailed deer. The Journal of Wildlife Management 56:645-650.

Eliason, S. L. 2003. Illegal hunting and angling: The neutralization of wildlife law violations. Society & Animals 11:225-243.

Etter, D. R., K. M. Hollis, T. R. Van Deelen, D. R. Ludwig, J. E. Chelsvig, C. L. Anchor, and R. E. Warner. 2002. Survival and movements of white-tailed deer in suburban Chicago, Illinois. The Journal of Wildlife Management 66:500-510.

Finder, R. A., J. L. Roseberry, and A. Woolf. 1999. Site and landscape conditions at white-tailed deer/vehicle collision locations in Illinois. Landscape and Urban Planning 44:77-85.

Fortin, N. L., P. J. Pekins, and K. A. Gustafson. 2015. Productivity measures of white-tailed deer in New Hampshire: assessing reduced recruitment. Wildlife Society Bulletin 39:56-64.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs 110:3-37.

Gaillard, J.-M., M. Festa-Bianchet, N. Yoccoz, A. Loison, and C. Toigo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics 31:367-393.

Gassett, J. 2001. Restoration of white-tailed deer in Kentucky: from absence to overabundance. Pages 119-123 *in* Large Mammal Restoration: Ecological and Sociological Challenges in the 21st Century. Island Press, Washington D.C., USA.

Gilbert, F. F. 1966. Aging white-tailed deer by annuli in the cementum of the first incisor. The Journal of Wildlife Management 30:200-202.

Grado, S. C., K. M. Hunt, and M. W. Whiteside. 2007. Economic impacts of white-tailed deer hunting in Mississippi.Proceedings of the Southeastern Association of Fish and Wildlife Agencies 61:59-67.

Green, G. S., H. J. Phillips, and S. K. Black. 1988. The Georgia deer jacker. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 42:558-565.

Grilo, C., F. Ascensão, M. Santos-Reis, & J. A. Bissonette. 2011. Do well-connected landscapes promote road-related mortality? European Journal of Wildlife Resources 57:707-716.

Halls, L. K. 1978. Big Game of North America: Ecology and Management. Stackpole Books, Harrisurg, Pennsylvania, USA.

Hast, J. T. 2010. Genetic diversity, structure, and recolonization patterns of Kentucky black bears. Thesis. University of Kentucky, Lexington, Kentucky, USA.

Haugen, A. O. 1975. Reproductive performance of white-tailed deer in Iowa. Journal of Mammalogy 56:151-159.

Haulton, S. M., W. F. Porter, and B. A. Rudolph. 2001. Evaluating 4 methods to capture white-tailed deer. Wildlife Society Bulletin 29:255-264.

Hebblewhite, M., and E. Merrill. 2008. Modelling wildlife–human relationships for social species with mixed-effects resource selection models. Journal of Applied Ecology 45: 834-844.

Hefflefinger, J. A. 2010. Taxonomy, evolutioinary history, and distribution. Pages 15-24 *in* D. G. Hewitt, editor. Biology and Management of White-tailed Deer. CRC Press, Boca Raton, Florida, USA.

Hoff, G. L., S. H. Richards, and D. O. Trainer. 1973. Epizootic of hemorrhagic disease in North Dakota deer. The Journal of Wildlife Management 37:331-335.

Homer, C.G., J.A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N.D. Herold, J.D. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing 81:345-354.

Hutto, R. L., S. M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for nonbreeding and breeding season use. The Auk 103:593-602.

Jacques, C. N., T. R. van Deelen, W. H. Hall, K. J. Martin, and K. C. Vercauteren. 2011. Evaluating how hunters see and react to telemetry collars on white-tailed deer. The Journal of Wildlife Management 75:221-231.

Jenkins, G., and T. Brunjes. 2013. Kentucky White-tailed deer report. Kentucky Department of Fish and Wildlife Resources. http://fw.ky.gov/pdf/1213deerreport.pdf. Accessed Sept. 2013.

Kaminsky, M. A. 1974. Analysis of the spatial and temporal occurrence of deer spotlighting violations in Virginia. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Keller, B. J., R. A. Montgomery, H. R. Campa, D. E. Beyer, S. R. Winterstein, L. P. Hansen, and J. J. Millspaugh. 2015. A review of vital rates and cause-specific mortality of elk (*Cervus elaphus*) populations in eastern North America. Mammal Review 45:146-159.

Kertson, B. N., R. D. Spencer, J. M. Marzluff, J. Hepinstall-Cymerman, and C. E. Grue. 2011. Cougar space use and movements in the wildland–urban landscape of western Washington. Ecological Applications 21:2866-2881.

Kilgo, J. C., H. S. Ray, C. Ruth, and K. V. Miller. 2010. Can coyotes affect deer populations in southeastern North America? Journal of Wildlife Management 74:929-933.

Kentucky State Police (KSP). 2015. Deer/auto collisions in Kentucky. Kentucky State Police. http://www.kentuckystatepolice.org/deerauto.htm. Accessed May 2014

Kunkel, K., and D. H. Pletscher. 1999. Species-specific population dynamics of cervids in a multipredator ecosystem. The Journal of Wildlife Management 63:1082-1093.

Lomas, L. A., and L. C. Bender. 2007. Survival and cause-specific mortality of neonatal mule deer fawns, north-central New Mexico. Journal of Wildlife Management 71:884-894.

Lopez, R. R., M. E. Vieira, N. J. Silvy, P. A. Frank, S. W. Whisenant, and D. A. Jones. 2003. Survival, mortality, and life expectancy of Florida key deer. The Journal of Wildlife Management 67:34-45.

Mantel, N. and Haenszel, W. 1959. Statistical aspects of the analysis of data from retrospective studies of disease. Journal of the National Cancer Institute 22:719–48.

Mattson, David J. 1990. Human impacts on bear habitat use. Bears: their biology and management. A Selection of Papers from the Eighth International Conference on Bear Research and Management: 33-56.

McCorquodale, S. M. 1999. Movements, survival, and mortality of black-tailed deer in the Klickitat Basin of Washington. The Journal of Wildlife Management 63:861-871.

McDonald, J. S., K. V. Miller. 2004. A history of white-tailed deer restocking in the United States, 1878 to 2004. Quality Deer Management Association. Bogart, Georgia, USA.

McNay, R. S., and J. M. Voller. 1995. Mortality causes and survival estimates for adult female Columbian black-tailed deer. The Journal of Wildlife Management 59:138-146.

Messier, F., C. Barrette, and J. Huot. 1986. Coyote predation on a white-tailed deer population in southern Quebec. Canadian Journal of Zoology 64:1134-1136.

Mich, P. M., L. L. Wolfe, T. M. Sirochman, M. A. Sirochman, T. R. Davis, W. R. Lance, and M. W. Miller. 2008. Evaluation of intramuscular butorphanol, azaperone, and medetomidine and nasal oxygen insufflation for the chemical immobilization of white-tailed deer, (*Odocoileus virginianus*). Journal of Zoo and Wildlife Medicine 39:480-487.

Moore, A., and D. B. Dotson. 2003. Soil survey of Clay county, Kentucky. Natural Resources Conservation Service. United States Department of Agriculture. https://www.nrcs.usda.gov/Internet/FSE.../kentucky/clay2003/clayKY2003.pdf Accessed Sept. 2013.

Murray, D. L., and B. R. Patterson. 2006. Wildlife survival estimation: recent advances and future directions. Journal of Wildlife Management 70:1499-1503.

Muth, R. M., and J. F. Bowe. 1998. Illegal harvest of renewable natural resources in North America: toward a typology of the motivations for poaching. Society & Natural Resources 11:9-24.

Nelson, M. E., and L. D. Mech. 1986. Mortality of white-tailed deer in northeastern Minnesota. The Journal of Wildlife Management 50:691-698.

Nettles, V., and D. Stallknecht. 1992. History and progress in the study of hemorrhagic disease of deer. Transactions of the North American Wildlife and Natural Resources Conference 57:499-516.

Ng, J. W., C. Nielson, and C. C. St Clair. 2008. Landscape and traffic factors influencing deer-vehicle collisions in an urban enviroment. Human-Wildlife Interactions 2:34-47.

Nicholson, M. C., R. T. Bowyer, and J. G. Kie. 1997. Habitat selection and survival of mule deer: tradeoffs associated with migration. Journal of Mammalogy 78:483-504.

Nixon, C. M. 1971. Productivity of white-tailed deer in Ohio. Ohio Journal of Science, 71:217-225.

Nixon, C. M., L. P. Hansen, P. A. Brewer, and J. E. Chelsvig. 1991. Ecology of white-tailed deer in an intensively farmed region of Illinois. Wildlife Monographs 118:3-77.

Nusser, S. M., W. R. Clark., D. L. Otis, and L. Huang. 2008. Sampling considerations for disease surveillance in wildlife populations. Journal of Wildlife Management 72.1:52-60.

Pais, R. C. 1987. Mortality, dispersal and habitat use of resident and translocated white-tailed deer does on the Cumberland Plateau of eastern Kentucky. Thesis. University of Kentucky, Lexington, Kentucky, USA.

Palsbøll, P. J., M. Berube, and F. W. Allendorf. 2007. Identification of management units using population genetic data. Trends in Ecology & Evolution 22:11-16.

Patterson, B. R., B. A. MacDonald, B. A. Lock, D. G. Anderson, and L. K. Benjamin. 2002. Proximate factors limiting population growth of white-tailed deer in Nova Scotia. The Journal of Wildlife Management 66:511-521.

Pedersen, M. A., S. M. Berry, and J. C. Bossart. 2008. Wounding rates of white-tailed deer with modern archery equipment. Procedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 62:31-34.

Phillips, J. 1983. A status report on Kentucky's deer herd. Pages 2-6 *in* Kentucky Happy Hunting Grounds. Kentucky Department of Fish and Wildlife Resources. Frankfort, Kentucky, USA.

Pojar, T. M., and D. C. Bowden. 2004. Neonatal mule deer fawn survival in west-central Colorado. Journal of Wildlife Management 68:550-560.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. The Journal of Wildlife Management 53:7-15.

Robinson, H. S., R. B. Wielgus, and J. C. Gwilliam. 2002. Cougar predation and population growth of sympatric mule deer and white-tailed deer. Canadian Journal of Zoology 80:556-568.

Romin, L. A., and J. A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24:276-283.

Samuel, W. 2007. Factors affecting epizootics of winter ticks and mortality of moose. Alces 43:39-48.

Severinghaus, C., and E. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 in W. P. Taylor, editor. The Deer of North America. The Stackpole Co., Harrisburg, Pennsylvania, USA.

Shope, R. E., L. G. MacNamara, and R. Mangold. 1960. A virus-induced epizootic hemorrhagic disease of the Virginia white-tailed deer (*Odocoileus virginianus*). The Journal of Experimental Medicine 111:155-170.

Smith, R. B., and F. G. Lindzey. 1982. Use of ultrasound for detecting pregnancy in mule deer. The Journal of Wildlife Management 46:1089-1092.

Spraker, T., M. Miller, E. Williams, D. Getzy, W. Adrian, G. Schoonveld, R. Spowart, K. I. O'Rourke, J. Miller, and P. Merz. 1997. Spongiform encephalopathy in free-ranging mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*) and rocky mountain elk (*Cervus elaphus nelsoni*) in northcentral Colorado. Journal of Wildlife Diseases 33:1-6.

StateFarm. 2013. Deer vehicle collisions decline: State Farm. in Claims Journal, http://www.claimsjournal.com/news/national/2013/10/01/237673.htm. Accessed Sept. 2013.

Stewart, C. M., W. J. McShea, and B. P. Piccolo. 2007. The impact of white-tailed deer on agricultural landscapes in 3 national historical parks in Maryland. The Journal of Wildlife Management 71:1525-1530.

Storm, D. J., C. K. Nielsen, E. M. Schauber, and A. Woolf. 2007. Space use and survival of white-tailed deer in an exurban landscape. Journal of Wildlife Management 71:1170-1176.

Therneau, T. M. 2015. A package for survival in R. Ver. 2.18. https://CRAN.R-project.org/package=survival. Accessed Feb. 2017

Unsworth, J. W., D. F. Pac, G. C. White, and R. M. Bartmann. 1999. Mule deer survival in Colorado, Idaho, and Montana. The Journal of Wildlife Management 63:315-326.

U.S. Climate Data (USCD). 2016. U.S. climate data; Manchester, Kentucky. http://www.usclimatedata.com/climate/manchester/kentucky/united-states/usky1114. Accessed Feb. 2016

United States Geological Survey (USGS). 2016. Distribution of chronic wasting disease in North America. United States Goelogical Survey. http://www.nwhc.usgs.gov/images/cwd/cwd_map.jpg. Accessed July 2016.

Van Deelen, T. R., H. Campa III, J. B. Haufler, and P. D. Thompson. 1997. Mortality patterns of white-tailed deer in Michigan's upper peninsula. The Journal of Wildlife Management 61:903-910.

Verme, L. J. 1963. Effect of nutrition on growth of white-tailed deer fawns. Michigan Department of Conservation, Game Division. Lansing, Michigan, USA.

Vilkitis, J. R. 1968. Characteristics of big game violators and the extent of their activity in Idaho. Thesis. University of Idaho, Moscow, Idaho, USA.

Waller, D. M., and W. S. Alverson. 1997. The white-tailed deer: a keystone herbivore. Wildlife Society Bulletin 25:217-226.

Wikramanayake, E. D., E. Dinerstein, J. G. Robinson, U. Karanth, A. Rabinowitz, D. Olson, T. Mathew, P. Hedao, M. Conner, G. Hemley, and D. Bolze. 1998. An ecology-based method for defining priorities for large mammal conservation: the tiger as case study. Conservation Biology 12:865-878.

Williams, E. 2005. Chronic wasting disease. Veterinary Pathology Online 42:530-549.

Williams, E. S., M. W. Miller, T. J. Kreeger, R. H. Kahn, and E. T. Thorne. 2002. Chronic wasting disease of deer and elk: a review with recommendations for management. The Journal of Wildlife Management 66:551-563.

Willis, D., C. Scalet, and L. D. Flake. 2008. Introduction to wildlife and fisheries. W.H. Freeman and Company. NewYork, NewYork, USA.

Woolf, A., and J. L. Roseberry. 1998. Deer management: our profession's symbol of success or failure? Wildlife Society Bulletin 26:515-521.

Vita

-Chatham, Virginia

-Virginia Polytechnic Institute and State University, Bachelor of Science in Wildlife Science

-Deer and elk technician at Kentucky Department of Fish and Wildlife Resources

-Caleb Anderson Haymes